Association Between Tibiofemoral Cartilage Proteoglycan Density and Knee Joint Stiffness During Walking 1 Month Post-ACL Reconstruction

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Background

- Individuals with a history of anterior cruciate ligament reconstruction (ACLR) are at high risk of posttraumatic knee osteoarthritis due to display aberrant gait biomechanics such as knee joint stiffness (KJS) (Figure 1).[1,2]
- Early signs of cartilage deterioration are indicative of increased T1 relaxation time (T1rho) which signify decreased proteoglycan content.[2]
- Prior studies have found significant correlation between increased T1rho values and abhorrent gait biomechanics at 6 months post-ACLR.[3]

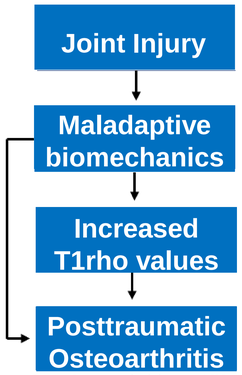


Figure 1. Progression of pathology post-ACLR

- While increased T1rho values and aberrant gait biomechanics are correlated at 6 months, it remains unclear if this association exists significantly at 1-month post-ACLR.

Purpose

- To identify associations between proteoglycan content in tibiofemoral cartilage and knee joint stiffness in patients 1 month after anterior cruciate ligament reconstruction.

Subjects & Study Design

- Gait biomechanics and self-reported knee function were assessed and MR imaging were conducted in one session 1 month after ACLR.
- Subjects were 13 individuals with unilateral ACLR (54% male; age 23.5 ± 6.2 yrs; mass 71.3 ± 13.7kg) (Table 1).

Subject Demographics	
Age	21.13 ± 6.20
Male	N = 7
Female	N = 6
Mass (kg)	71.29 ± 13.75
Height (m)	1.74 ± 0.09

Table 1. Breakdown of participant demographics

Methods

Gait Biomechanics Assessment

- Subjects walked barefoot at their preferred speed across force platforms (Image 1).
- Peak internal knee extension moments and knee flexion angles were calculated during the first 50% of stance for each participant.
- Knee joint stiffness was calculated as peak internal knee extension moment divided by peak knee flexion angle.

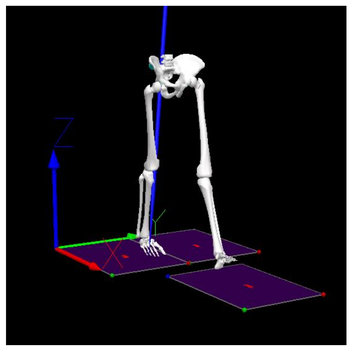


Image 1. Biomechanical data displayed in processing software

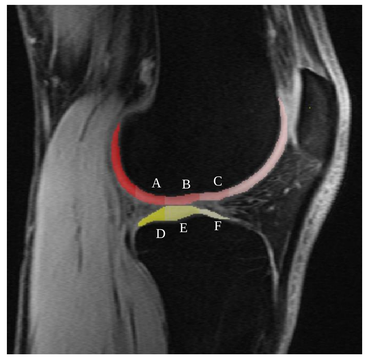


Image 2. Zero millisecond spin lock image of tibiofemoral cartilage in ITKSnap

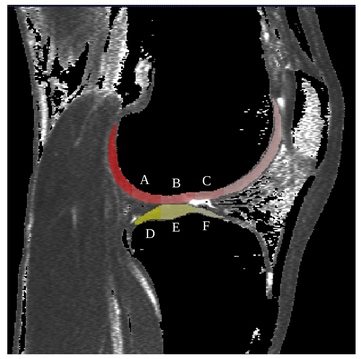


Image 3. Relaxation map of tibiofemoral cartilage in ITKSnap

MRI segmentation

- Proteoglycan content of tibiofemoral cartilage was identified and analyzed via segmentation in ITKSnap software (Images 2-5).
- Average relaxation times per cartilage region were calculated for regions A, B, and C on the femur and D, E, and F on the tibia (Images 2 & 3).
- Segmentation was completed via zero-millisecond spin lock image overlaid on a T1rho relaxation map.

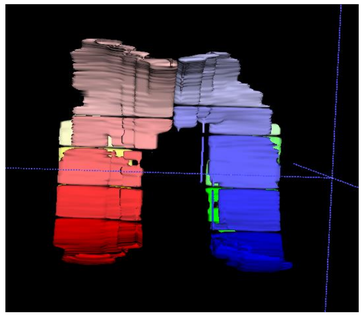


Image 4. Superior view of segmented tibiofemoral cartilage.

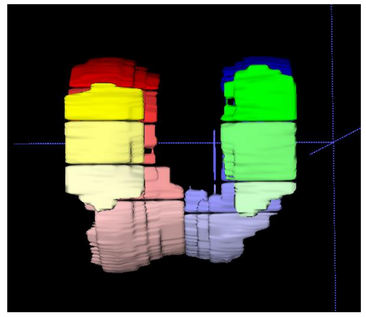


Image 5. Inferior view of segmented tibiofemoral cartilage.

Statistical Analysis

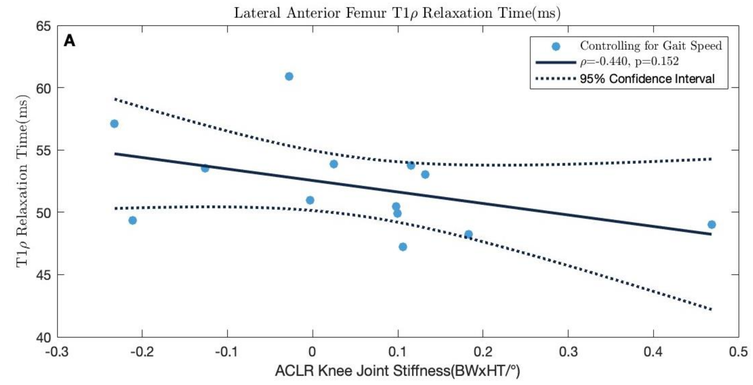
- A partial Pearson correlation while controlling for gait speed were conducted to analyze the associations between T1rho values and knee joint stiffness.

Results

- No significant associations were found ($p > 0.05$).

Associations Between Femoral Cartilage and Knee Joint Stiffness						
	Lateral Posterior	Lateral Middle	Lateral Anterior	Medial Posterior	Medial Middle	Medial Anterior
Rho	0.119	-0.137	-0.440	-0.234	0.122	0.097
P-Value	0.713	0.694	0.152	0.465	0.707	0.765

Associations Between Tibial Cartilage and Knee Joint Stiffness						
	Lateral Posterior	Lateral Middle	Lateral Anterior	Medial Posterior	Medial Middle	Medial Anterior
Rho	0.448	0.065	0.047	-0.199	0.120	0.282
P-Value	0.167	0.842	0.884	0.535	0.709	0.375



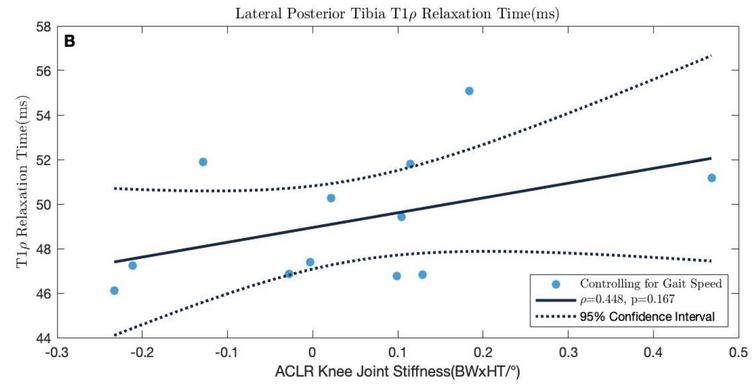


Figure 2. Scatterplots of calculated knee joint stiffness controlling for gait speed

Discussion

- No significant associations were found between T1rho relaxation times and knee joint stiffness 1-month post-ACLR.
- 1 month after reconstruction may not be sufficient time for pathologies to develop.
- Some patients are limited in weight-bearing or range of motion, which will increase KJS values without increasing T1rho values.
- Small sample size (N=13) may not have captured real associations.
- Other methods of calculating knee joint stiffness may be more appropriate in capturing existing associations at 1-month post-ACLR.

References

1. Garcia, S. A., Johnson, A. K., Brown, S. R., Washabaugh, E. P., Krishnan, C., & Palmieri-Smith, R. M. (2023). Dynamic knee stiffness during walking is increased in individuals with anterior cruciate ligament reconstruction. *Journal of biomechanics*, *146*, 111400. https://doi.org/10.1016/j.jbiomech.2022.111400

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